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THE EFFECT OF TEMPERATURE ON VELOCITY OF LONGITUDINAL WAVES IN ROCKS AT HIGH PRESSURES

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THE EFFECT OF TEMPERATURE ON VELOCITY OF LONGITUDINAL WAVES IN ROCKS AT HIGH PRESSURES

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An oven (fig. 1) was constructed for the study of the effects of temperature on the velocity of elastic waves; the oven was installed in a high-pressure chamber, where the compression of nitrogen gas permitted pressures of up to five kilobars. The apparatus and the method of measuring the speed of the elastic waves are described in the earlier work [1]. However, in connection with the increase in temperatures, it was necessary to make some changes in the method. The temperature of the rock sample was measured by a Chromel-Alumel thermocouple, the junction of which was inserted into the model through a specially-welded aperture 2.5 mm. in diameter and 10 mm. long. Preliminary tests showed that such a placement of the thermocouple allowed a more accurate reading of the temperature of the sample, and had no effect on the determination of the speed of the wave. Significant heat elimination through the body of the chamber complicated the heating of the sample, especially at high pressures. Use of quartz tubing installed between the walls of the chamber and the furnace, and of an asbestos stopper effectively reduced heat elimination. Following the lessons learned from earlier investigations, [2-4], pressure was created in the chamber first, after which the sample was heated. The speed of the longitudinal waves was measured during the heightening and lowering of temperatures at several constant pressures.

As anticipated, the speed of the longitudinal waves decreased as the temperature was increased. However, different rocks reacted in different ways to the test. Fig. 2 shows the results for the experiment with samples of limestone from the Pripyatskii basin, at a depth of 2890m. The limestone is composed of ninety three percent calcite, has a density of 2.9 g/cm. 3 and has very little porosity. As

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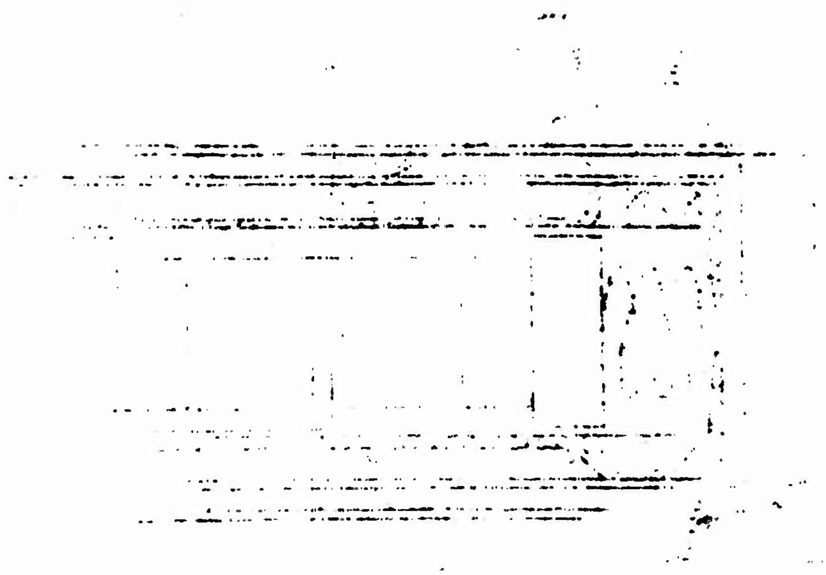

Figure 1.- diagram of the oven

1= body; 2 = mica isolate; 3 = heater; 4 = fire clay; 5 = thermocouple; 6= thermocouple shield (porcelain tubing); 7 = rock sample; 8= piezo-pickup; 9 = thermal-isolating stopper; 10 = quartz tubing.

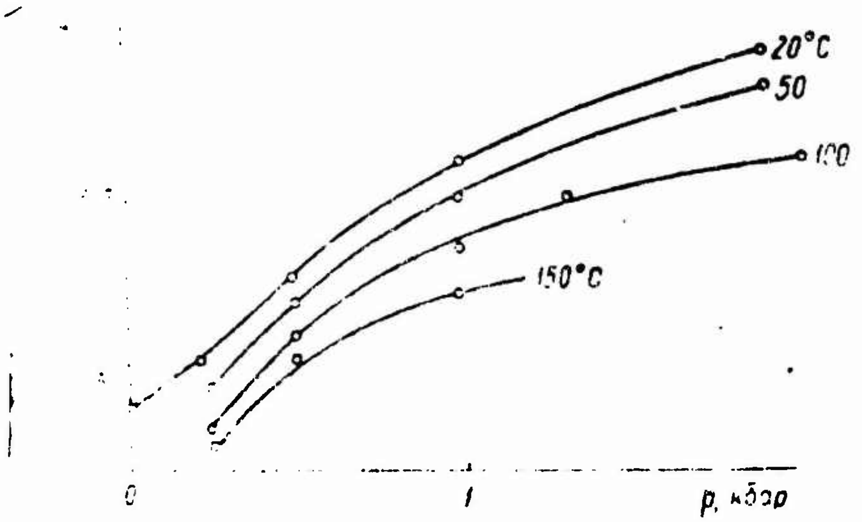

Figure 2 .- Isothermic curve of the speed function of the longitudinal waves according to pressure for limestone.

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shown in fig. 2, the curve showing the dependence between the speed (of the wave) and the pressure is distributed lower at high temperatures than it is at room temperature. At constant pressures (0.5 kbar; 1 kbar, etc.) the speed of the wave in the limestone gradually decreases with temperature. No jumps in the speed curve of the temperature function were observed at such pressures. Temperatures in this experiment reached the range of 120-170 degrees Centigrade. In experiments conducted with granite from Ukraine and Voronezh crystalline massifs having a porosity from 1.8 to 2.6 percent, at pressures less than one kbar, an increase in the temperature over one hundred degrees Centigrade lead to abrupt and irreversible decreases in the speed of the waves. From fig. 3 it is apparent that the heating of granite in excess of one hundred degrees Centigrade at pressures of three hundred bars causes a significant reduction in the speed the waves. After cooling, the speed of the longitudinal waves remained low; event at pressures of five hundred bars the speed of the waves was lower than at atmospheric pressures, before heating.

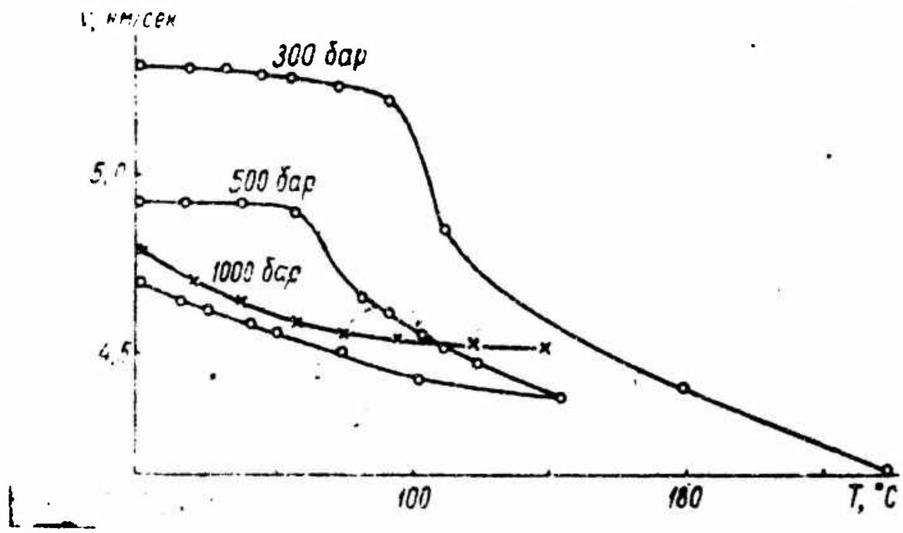

Figure 3.- Isobaric curve of the speed function according to temperature for granite.

In figure 3 is shown the forward (during heating) and backward (during cooling) path of the dependence of the speed on temperature, at five hundred bars pressure. In this case, jumps (in the curve) did occur at lesser temperatures. This is explained by the weakening of the rock because of micro-fissures, appearing in the granite in the first test. At temperatures higher than one hundred degrees Centigrade, water associated with the rock begins to evaporate; since the pressure is low, this evaporation is accompanied by the intensive formation of micro-fissures. At pressures of one and two kbars, no jumps were observed on the corresponding curve (even though heating was continued up to one hundred and forty degrees Centigrade). However, the speed of the waves did not attain its original value, which testifies to significant structural changes having occured previously in the rock.

In such a manner, during the heating of rock in the above temperature ranges, the speed of the longitudinal waves decreases weakly - if under these conditions no structural changes occur in the rock, and no micro-fissures develop. In the opposite case, abrupt reductions (in the form of jumps) occur in the speed of the waves. In connection with this, temperature irregularities for the duration of their existence in the depths of the earth [5], may also call forth sharp reductions in the speed of elastic waves.